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(54) **Chiral diphosphine compound, intermediate for preparing the same, transition metal complex having the same diphosphine compound as ligand and asymmetric hydrogenation catalyst**

Chirale Diphosphin-Verbindung, Zwischenprodukte zu ihrer Herstellung, Übergangsmetall-Komplexe davon und asymmetrischer Hydrierungskatalysator

Diphosphine chirale, intermédiaires pour sa préparation, complexes de ladite diphosphine avec des métaux de transition et catalyseur d'hydrogénation asymétrique

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(56) References cited:
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EP-A- 0 771 812
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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a novel optically active diphosphine compound, an intermediate for preparing the same, a transition metal complex having the same diphosphine compound as a ligand and a transition metal catalyst useful for a variety of asymmetric synthetic reactions.

2. Description of the Related art

[0002] There have hitherto been many reports on transition metal complexes which can be utilized for asymmetric synthesis such as asymmetric hydrogenation reaction, asymmetric isomerization reaction, asymmetric hydrosilylation reaction and the like. Inter alia, complexes in which transition metal complexes such as ruthenium, rhodium, iridium, palladium are coordinated with an optically active tertiary phosphine compound have potent performance as a catalyst for an asymmetric reaction.

[0003] In order to further enhance the performance, many phosphine compounds having various structures have hitherto been developed (Kagakusosetsu 32, edit. by Nippon Chemistry Society, "Chemistry Of Organometallic Complexes », 237-238 (1982) ; « Asymmetric Catalysis in Organic Synthesis », Ryoji Noyori, A Wiley-Interscience Publication).

EP-A-0643065 discloses optically active diphosphine compounds based on a biphenyl backbone and the use thereof in transition metal complexes suitable for catalysed asymmetric hydrogenation.

WO-A-96/01831 discloses chiral diphosphines constituted by an aromatic pentatomic biheterocyclic system.

EP-A-0771812, which is a document of the state of the art only under article 54(3) EPC, discloses 2,2'- diphosphino -1,1'-binaphthyl compounds.

[0004] 2,2'-bis (diphenylphosphino)-1,1'-binaphthyl (hereinafter referred to "BINAP"), inter alia, is one of the excellent optically active phosphines, and a rhodium complex having the BINAP as a ligand (JP-A 55-61973) and a ruthenium complex (JP-A 61-6390) have been previously reported.

[0005] Further, it has been reported that a rhodium complex (JP-A No. 60-199898) and a ruthenium complex (JP-A 61-63690) having 2,2'-bis(di-(p-tolyl) phosphino)-1,1'-binaphthyl (hereinafter referred to as "p-TolBINAP") as a ligand give the better results in an asymmetric isomerization reaction. Further, it has been reported in JP-A No. 3-255090 that a ruthenium complex of 2,2'-bis(di-(3,5-dialkylphenyl)phosphino)-1,1'-binaphthyl gives the better results in a reaction for the asymmetric hydrogenation of β-ketoesters.

[0006] However, selectivities (diastereoselectivity, enantioselectivity) and catalytic activity are not sufficient depending upon an objective reaction and reaction substrate and, thus, improvement in a catalyst is occasionally demanded.

SUMMARY OF THE INVENTION

[0007] Accordingly, an object of the present invention is to provide a novel phosphine compound having the excellent performance (diastereoselectivity, enantioselectivity, catalytic activity) as a catalyst for an asymmetric reaction, in particular, an asymmetric hydrogenation reaction.

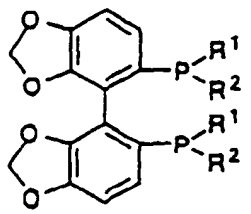
[0008] Especially, a transition metal complex having optically active ((5,6),(5',6')-bis(methylenedioxy)biphenyl-2,2'-diyl)bis(diphenylphosphine) (hereinafter referred to as "SEGPHOS" in some cases) is effective for an asymmetric hydrogenation reaction.

[0009] Another object of the present inventors is to provide a catalyst comprising the phosphine compound and transition metal selected from Ru, Ir, Pd, Rh or Ni.

PREFERRED EMBODIMENTS OF THE INVENTION

[0010] The present invention will be described in detail below.

[0011] One of diphosphine compounds of the present invention is represented by the following formula (1):

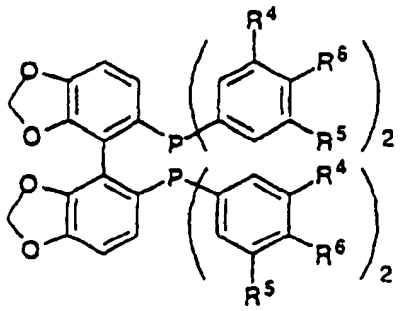


(1)

where R^1 and R^2 represent independently cycloalkyl group, unsubstituted or substituted phenyl group, or five-membered heteroaromatic ring residue.

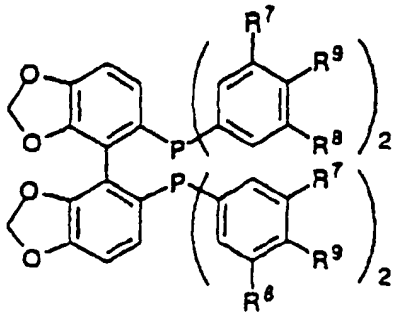
[0012] The cycloalkyl in the R^1 and R^2 are cyclopentyl group, cyclohexyl group or cycloheptyl group. The five-membered heteroaromatic ring in R^1 and R^2 is 2-furyl group, 3-furyl group, 2-benzofuryl group or 3-benzofuryl group. Examples of substituents in the substituted phenyl are C_1-C_4 alkyl, C_1-C_4 alkoxy group, di-(lower alkyl)amino group or halogen atom. As used herein, lower alkyl is alkyl group having 1 to 5 carbon atoms.

[0013] Among aforementioned compounds, preferable compound is represented by the formula (5):



(5)

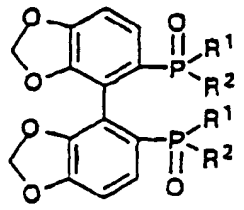
where R^4 and R^5 represent independently hydrogen atom, C_1-C_4 alkyl group, C_1-C_4 alkoxy group; R^6 represents hydrogen, C_1-C_4 alkyl group, C_1-C_4 alkoxy group or di(C_1-C_4 alkyl)-amino group, and more preferable compounds are represented by the formula (6):



(6)

where R^7 and R^8 are the same or different and represent hydrogen atom, t-butyl group, n-butyl group, n-propyl group, isopropyl group, ethyl group or methyl group; R^9 represents hydrogen atom, t-butoxy group, isopropoxy group, ethoxy group or methoxy group.

[0014] Another compound of the present invention is represented by the following formula (2):



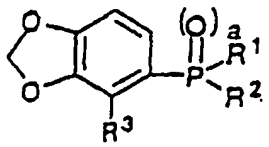
(2)

where R^1 and R^2 are as defined above.

[0015] The compound of the formula (2) is an intermediate for preparing the compounds of the aforementioned formula (1).

[0016] The present invention includes racemic compounds and optically active compounds of the aforementioned compounds.

[0017] Other diphosphine compound of the present invention is represented by the following formula (3):



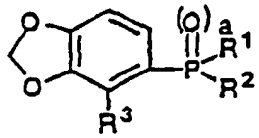
(3)

where R^1 and R^2 are the same as defined above; R3 represents hydrogen or a halogen atom; and letter a represents 0 or 1.

[0018] The compound of the formula (3) is an intermediate for preparing the compound of the aforementioned formula (2).

The invention also relates to a process for the preparation of a compound of a formula (1) said process comprising the steps of :

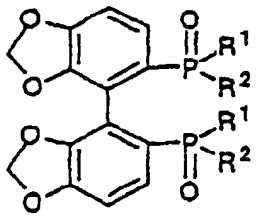
a) reacting a 3,4-methylenedioxyhalogenobenzene successively with Mg, a corresponding derivative of phosphinyl chloride and optionnaly a halogen, in an appropriate solvent, thereby obtaining a compound having formula (3) :



(3)

in which R^1 and R^2 independently signify cycloalkyl group, unsubstituted or substituted phenyl group, or five-membered heteroaromatic ring residue and R^3 signifies hydrogen or a halogen atom ; and where letter a signifies 1 ;

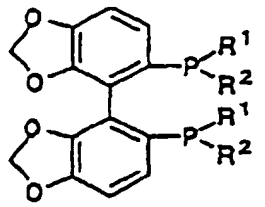
b) condensing said compound having formula (3) into a compound having formula (2) :



(2)

in which R^1 and R^2 have the same meaning as described above ; and

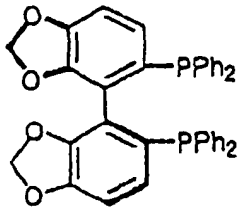
c) reducing said compound having formula (2), thereby obtaining a compound having formula (1) :



(1)

in which R^1 and R^2 have the same meaning as described above.

[0019] In order to avoid complexity, a representative embodiment of this process for preparing the present compounds is now explained by referring to a compound of the following (7);(-)-((5,6), (5',6')-bis(methylenedioxy)biphenyl-2,2'-diyl)-bis(diphenylphosphine) (hereinafter referred to as "(-)-SEGPHOS" in some cases) among the compounds included in the present invention. However, the present invention is not limited thereto.



(7)

[0020] That is, a magnesium and 3,4-methylenedioxybromobenzene (8) are reacted to obtain a Grignard reagent, on which is acted diphenylphosphinyl chloride to obtain diphenyl(3,4-methylenedioxyphenyl)phosphine oxide (3a) (R^1 and R^2 = Ph, R^3 = H).

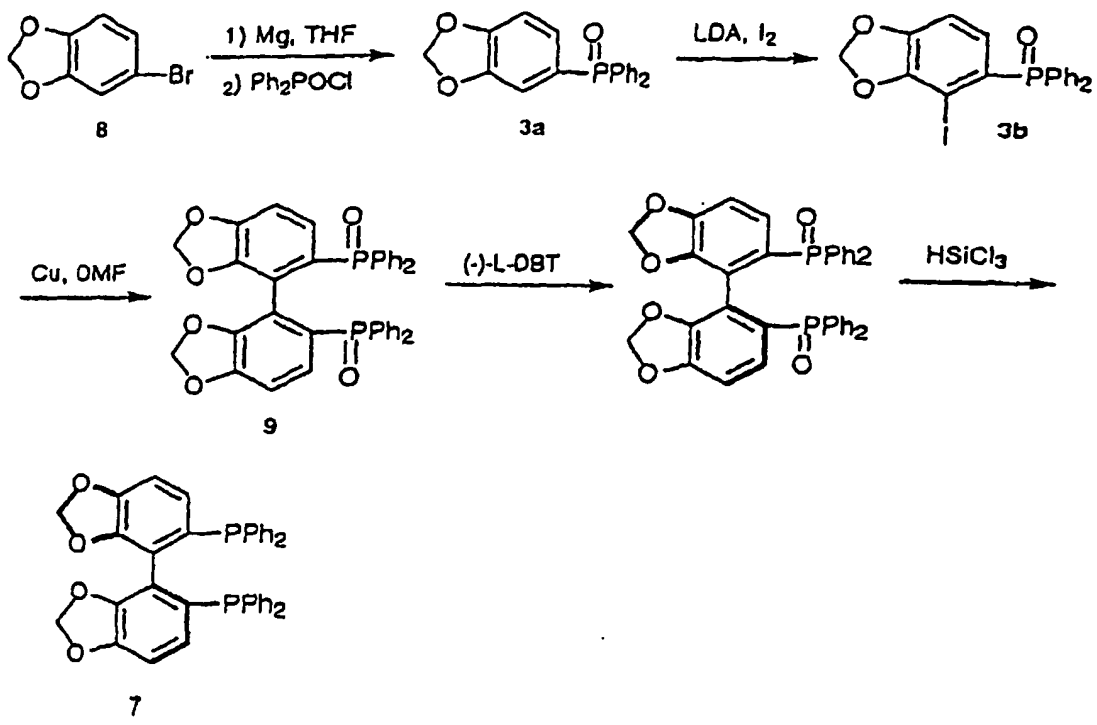
[0021] This compound (3a) can be reduced by the known method to obtain diphenyl(3,4-methylenedioxyphenyl)-phosphine.

[0022] (3a) and iodine are reacted in the presence of lithium diisopropylamide to obtain an iodocompound (3b).

[0023] Then, the iodocompound (3b) is heated in dimethylformamide (hereinafter referred to as "DMF") in the presence of copper powders to obtain racemic diphosphine oxide (9) (R^1 and R^2=Ph).

[0024] The racemic phosphine oxide can be resolved with (-)-L-dibenzoyltartaric acid by forming a crystalline equimolar complex. Reduction of the resolved phosphine oxide with trichlorosilane glue (-)-SEGPHOS in good yield.

(Scheme 1)



[0025] In addition, (+)-SEGPHOS can be obtained by optical resolution using (+)-D-benzoyltartaric acid.

[0026] Further, the present diphosphine compound having a substituent in phenyl ring can be prepared by using a diarylphosphinyl chloride having a substituent on its phenyl ring in place of the diphenylphosphinyl chloride.

[0027] The compound (7) (R^1 and R^2 = Ph) which is optically active among the present compounds can be obtained as below. Enantiomers can be resolved by liquid chromatography using an optically active column, and they are reduced in the usual manner.

[0028] Among the present compounds, the compound (1), in particular the optically active compound (1) is useful as a ligand for a transition metal complex catalysed asymmetric reaction. In addition, among the present compounds (1), the racemic one is also useful as an intermediate for preparing the optically active compounds (1).

[0029] Examples of the transition metal include rhodium, ruthenium, iridium, palladium, nickel.

[0030] The transition metal complex of the invention have the formula (4) :

$$MmLnXpSq \qquad (4)$$

where M represents a transition metal selected from rhodium, ruthenium, iridium, palladium and nickel, L represents the diphosphine compound of formula (1), (5) or (6) as above defined and is optically active, and X and S represent as follows :

when M = Rh, then X = Cl, Br, I, m=n=p=2, q=0
when M = Ru, then m=n=1, X=OAc, p=2, q=0
or X = Cl, S=NEt3, m=n=2, p=4, q=1
or X = methylallyl, m=n=1, p=2, q=0
when M = Ir, then X = Cl, Br, I, m=n=p=2, q=0
when M = Pd, then X = Cl, m=n=p=1, p=2, q=0
or X = p-allyl, m=n=p=2, p=0
when M = Ni, then X = Cl, Br, I, m=n=1, p=2, q=0

(Ac represents acetyl group)

[0031] The invention also relates to a catalyst comprising a transition metal complex of formula (10):

$$[MmLnXpSq]Yr \quad (10)$$

where M represents a transition metal selected from rhodium, ruthenium, iridium, palladium and nickel, L represents the diphosphine compound of formula (1), (5) or (6) as above defined and is optically active, and X, S and Y represent as follows :

when M = Rh, then X = cod, nbd, Y=BF4, ClO4, PF6, BPh4, m=n=p=r=1, q=0
when M = Ru, then X = Cl, Br, I, S=benzene, p=cymene, Y=Cl, Br, I, m=n=p=q=r=1
or Y=BF4, ClO4, PF6, BPh4, m=n=1, p=q=0, r=2
when M = Ir, then X = cod, nbd, Y=BF4, ClO4, PF6, BPh4, m=n=r=1, p=1, q=0
when M = Pd, then Y=BF4, ClO4, PF6, BPh4, m=n=r=1, p=q=0 (cod represents 1,5-cyclooctadiene, nbd represents norbornadiene, and Ph represents phenyl group).

[0032] The transition metal complexes of the present invention can be prepared by the known methods.

[0033] Here, with respect to symbols used in the formulae of the transition metal complexes described below, L represents the optically active compounds among the present invention, cod represents 1, 5-cyclooctadiene, nbd represents norbornadiene, Ph represents phenyl group, and Ac represents acetyl group.

Rhodium complex :

[0034] Specifically, a rhodium complex can be prepared, for example, by reaction of bis(cycloocta-1,5-diene)rhodium (I) tetrafluoroborate with the present SEGPHOS according to a method described in "Experimental Chemistry, 4th edition", volume 18, Organometallic Complexes, pp.339-344, Ed. Chemical Society of Japan, 1991, published by Maruzen. Examples of the rhodium compound include the following:
$[Rh(L)Cl]_2$, $[Rh(L)Br]_2$, $[Rh(L)I]_2$,
$[Rh(cod)(L)]BF_4$, $[Rh(cod)(L)]BPh_4$,
Rh(cod)(L),
$[Rh(nbd)(L)]BF_4$, $[Rh(nbd)(L)]ClO_4$,
$[Rh(nbd)(L)]PF_6$, $[Rh(nbd)(L)]Bph_4$

Ruthenium complex:

[0035] A ruthenium complex can be prepared by heating $[Ru(cod)C_{12}]n$ and SEGPHOS at reflux with toluene in the presence of triethylamine as described in the literature (T. Ikariya, Y. Ishii, H. Kawano, T. Arai, M. Saburi, S. Yoshikawa, and S. Akutagawa, J. Chem. Soc., Chem. Commun., 922 (1988)). Alternatively, the ruthenium complex can be obtained by heating $[Ru(p\text{-cymene})I_2]_2$ and SEGPHOS in methylene chloride and ethanol under stirring according to a method described in the literature (K. Mashima, K. Kusano, T. Ohta, R. Noyori, H. Takaya, J. Chem. Soc., Chem. Commun., 1208 (1989)). Examples of the ruthenium complex are as follows:
$Ru(OAc)_2(L)$ $Ru_2Cl_4(L)_2NEt$,
[RuCl(benzene)(L)], [RuBr(benzene)(L)]Br, [RuI(benzene)(L)]I,
[RuCl(p-cymene)(L)]Cl, [RuBr(p-cymene)(L)]Br, [RuI(p-cymene)(L)]I,
$[Ru(L)](BF4)_4$, $[Ru(L)](ClO_4)_2$, $(Ru(L)](PF_6)_2$,$[Ru(L)](BPh_4)_2$

Iridium complex:

[0036] An iridium complex can be prepared by reaction of SEGPHOS with $[Ir(cod)(CH_3CN)_2]BF_4$ in tetrahydrofuran under stirring according to a method described in the literature (K. Mashima, T. Akutagawa, X. Zhang, T. Taketomi, H. Kumobayashi, S. Akutagawa, J. Organomet., Chem. 1992, 428, 213). Examples of the iridium complex are as follows:
$[Ir(L)Cl]_2$, $[Ir(L)Br]_2$, $[Ir(L)I]_2$,
$[Ir(cod)(L)]BF_4$, $[Ir(cod)(L)]ClO_4$,
$[Ir(cod)(L)]PF_6$, $[Ir(cod)(L)]BPh_4$,
$[Ir(nbd)(L)]BF_4$, $[Ir(nbd)(L)]Cl_4$
$[Ir(nbd)(L)]PF_6$, $[Ir(nbd)(L)]BPh_4$

Palladium complex :

[0037] A palladium complex can be prepared by reaction of SEGPHOS with π-allylpalladium chloride according to a method described in the literature (Y, Uozumi and T, Hayashi, J. Am. Chem. Soc., 1991, 113, 9887). Examples of the palladium complex are as follows: $PdCl_2(L)$, (p-allyl)Pd(L), $[(Pd(L)]BF_4$, $[Pd(L)]ClO_4$, $[(Pd(L)]PF_6$, $[(Pd(L)]BPh_4$

Nickel complex:

[0038] A nickel complex can be prepared according to a method described in, for example, "Experimental Chemistry, 4th edition" vol. 18, Organometallic complexes, p. 376, Ed. Chemical Society of Japan, 1991, published by Maruzen, or alternatively, can be prepared by dissolving SEGPHOS and nickel chloride with a mixed solvent of isopropanol and methanol, followed by heating under stirring according to a method described in the literature (Y. Uozumi and T, Hayashi, J. Am. Chem. Soc., 1991, 113, 9887).

[0039] Examples of the nickel complex are as follows:

$NiCl_2(L)$, $NiBr_2(L)$, $NiI_2(L)$

[0040] The transition metal complexes having this novel optically active diphosphine compound as a ligand are useful as a catalyst for an asymmetric hydrogenation reaction. Upon the use of the complex as a catalyst, the complex may be used after enhancing the purity thereof or without purification thereof.

[0041] Among the aforementioned transition metal complexes, in particular, a complex containing ruthenium and SEGPHOS which is an optically active diphosphine compound gives higher enantioselectivity in the asymmetric hydrogenation of 2-oxo-1-propanol than ruthenium complexes having the ligand such as BINAP, p-TolBINAP and the like. In addition, a complex containing ruthenium and ((5,6),(5',6')-bis(methylendioxy)biphenyl-2,2'-diyl)bis(bis-3,5-dimethylphenyl)phosphine (hereinafter referred to as "DM-SEGPHOS") as a ligand gives the equivalent enantioselectivity to that of ruthenium complexes of BINAP, p-TolBINAP and the like in a reaction for asymmetric hydrogenation of methyl 2-benzamidomethyl-3-oxybutyrate and give higher diastereoselectivity and catalytic activity.

[0042] Thus, the novel diphosphine compounds of the present invention are useful as, in particular, a ligand for a transition metal complex. In addition, the transition metal complexes are useful catalyst for asymmetric reaction and are extremely industrially useful.

[0043] The following Examples and Use Examples further illustrate the present invention in detail but are not to be construed to limit the scope thereof.

EXAMPLES

[0044] Apparatuses used for determining physical properties in respective Examples are as follows:

Nuclear magnetic resonance: ^1H NMR Bruker AM400 (400MHz)
^{31}P NMR Bruker AM400 (162MHz)
Melting point: Yanaco MP-500D
Optical rotation: Nihon Bunkoh Co., Ltd. DIP-4
Gas chromatography GLC: Hewlett Packard 5890-11
High-performance liquid chromatography HPLC: LC10AT & SPD10A manufactured by Shimadzu Corporation
Mass spectrometry (MASS): M-80B manufactured by Hitachi

Example 1

Synthesis of diphenyl((3,4)-methylenedioxyphenyl)phosphine oxide

[0045] A magnesium (12.4 g, 511 mmol) was charged into a four-necked round-bottomed flask, equipped with a thermometer, a condenser and a pressure equalizing dropping funnel, and then which was completely replaced with nitrogen, and 30 ml of anhydrous tetrahydrofuran was added thereto. To this solution was added a 200 ml solution of 4-bromo-1,2-methylenedioxybenzene (93.6 g, 465 mmol) (manufactured by Tokyokasei) in tetrahydrofuran (hereinafter referred to as "THF") dropwise over 2.5 hours under water-cooling stirring and stirring was further continued at room temperature for 3 hours. To the resulting mixture was added 100 g (423 mmol) of diphenyl phosphinyl chloride dropwise over 2 hours under ice-cooling and stirring was continued at room temperature for 15 hours. Thereafter, 30 ml of water was added thereto under ice-cooling to stir for 30 minutes, then 150 ml of 1N hydrochloric acid was added thereto, followed by stirring for 1.5 hours. The reaction product was extracted with 300 ml of ethyl acetate, washed successively with 150 ml of 1N hydrochloric acid, 150 ml of an aqueous saturated sodium bicarbonate and 150 ml of water, and the solvent was distilled off under reduced pressure.

[0046] The resulting crystals dissolved in 150 ml of toluene under heating, followed by recrystallization at -5 °C to obtain 127 g of the titled compound.
mp : 127-128°C
1H-NMR(CDC) : D 6.01(2H,S), 6.88(1H,dd,J=10.3,2.4 Hz), 7.08(1H,dd,J=10.0 Hz), 7.18(1H,ddd,J=13.5,10.3,2.4Hz), 7.43-7.48(4H,m), 7.51(2H,m), 7.64-7.70(4H,m)
31P-NMR(CDCl3) : d29.8

Example 2

Synthesis of diphenyl(2-iodo-(3,4)-methylenedioxyphenyl)phosphine oxide

[0047] 20.0 g (62.1 mmol) of diphenyl((3,4)-methylenedioxyphenyl)phosphine oxide was dissolved in 250 ml of THF under a nitrogen stream. To this solution was added 93 ml of a solution of lithiumdiisopropylamide in THF (0.7 M) dropwise at - 78 °C over 30 minutes, and stirring was continued at the same temperature for 1.5 hours. The resulting mixture was added dropwise to a solution of 16.5 g (65.2 mmol) of iodine in 50 ml of THF at -78 °C for 30 minutes and, thereafter, a temperature was raised to 0 °C, followed by stirring for 1 hour. After THF was distilled off, the residue was dissolved in 500 ml of ethyl acetate, washed successively with 500 ml of an aqueous saturated ammonium chloride and 300 ml of a saturated sodium chloride and dried over anhydrous magnesium sulfate. After the solvent was distilled off, the residue was purified by silica gel column chromatography (eluent hexane:ethyl acetate = 2:5) to obtain 22.2 g of the titled compound,
mp : 191-193°C
1H-NMR(CDCl3) : d6.08(2H,s), 6.68(1H,dd,J=8.0,2.2Hz), 6.74(2H,dd,J=13.3, 8.0 Hz) 7.47-7.49(4H,m), 7.54(2H,dd, J=7.5, 1.6 Hz), 7.68-7.73(4H,m)
31P-NMR(CDCl3) : d33.2

Example 3

Synthesis of (±)-((5,6),(5',6')-bis(methylenedioxy)biphenyl-2,2'-diyl)bis(diphenylphosphine oxide)

[0048] A mixture of 58.40 g (0.130 ml) of the iodide obtained in Example 2, 24.85 g (0.390 mol) of copper powders and 228 ml of DMF was heated at a bath temperature of 140 °C for 8 hours under stirring. The reaction mixture was filtered with a pad of celite and the solvent was distilled off under reduced pressure. The residue was dissolved in 900 ml of methylene chloride, washed with 500 ml of an aqueous saturated ammonium chloride and 300 ml of saturated sodium chloride and dried over anhydrous magnesium sulfate. The solvent was distilled off under reduced pressure and the residue was purified by silica gel column chromatography. The resultant solid was recrystallized from a mixed solvent of 45 ml of ethyl acetate and 5 ml of hexane to obtain 18,5 g of the titled compound. The mother liquor was concentrated and washed with diisopropyl ether to obtain 12.10 g of the titled compound.
mp : 230-232°C
1H-NMR(CDCl3) : d5.26(2H,d,J=1.5Hz), 5.72(2H,d,J=1.6Hz), 6.65(2H,dd,J=8.1,2.1 Hz) 6.77(2H,dd,J=14.1,8.1 Hz), 7.28-7.72(20H,m)
31P-NMR(CDCl3) : d-12.6
EI-MS m/z 642(M+)

Example 4

Optical resolution of (±)-((5,6),(5',6')-bis(methylenedioxy)biphenyl-2,2'-diyl)bis(diphenylphosphine oxide)

[0049] A solution of 12.07 g (18.8 mmol) of (±)-((5,6),(5',6')-bis(methylenedioxy)biphenyl-2,2'-diyl)bis(diphenylphosphine oxide (hereinafter referred to as (±)-SEGPHOSO$_2$ in some cases) in 60 ml of chloroform was refluxed. A solution of 7.43 g (19.7 mmol) of (-)-dibenzoyl-L-tartaric acid in 20 ml of ethyl acetate was added dropwise thereto. After stirring for 30 minutes, the solvent was distilled off under reduced pressure. The residue was dissolved in 110 ml of ethyl acetate, which was heated to 60 °C and 40 ml of carbon tetrachloride was added thereto. Upon cooling to room temperature, 5.51 g of precipitated solid was obtained by filtration. The solid was washed with a mixed solvent of 40 ml of ethyl acetate, 10 ml of carbon tetrachloride and 2 ml of ethanol to give 4.53 g of white solid. The solid was dissolved in 40 ml of chloroform, and 20 ml of 1N aqueous sodium hydroxide was added thereto, followed by stirring at room temperature for 1 hour. The organic layer was separated, washed successively with water and an aqueous sodium chloride solution and dried over anhydrous sodium sulfate.

[0050] The solvent was distilled off under reduced pressure, the residue was dissolved in 30 ml of chloroform, and

then 1.70 g (4.51 mmol) of (-)-dibenzoyl-L-tartaric acid was added and the mixture refluxed for 30 minutes and cooled to room temperature. The precipitat (2.77 g) was dissolved in chloroform, and 1N aqueous sodium hydroxide solution was added, followed by stirring at room temperature for 1 hour. The organic layer was separated, washed successively with water and an aqueous sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was distilled off under reduced pressure to obtain 1.91 g of (-)-((5,6),(5',6')-bis(methylenedioxy)biphenyl-2,2'-diyl)bis(diphenylphosphine oxide) (hereinafter referred to as "(-)-SEGPHOS$_2$) with 100% ee.
[a]D24-161,9°(c0.063,CHCl3)

Example 5

Synthesis of (-)-((5,6),(5',6')-bis(methylenedioxy)biphenyl-2,2'-diyl)bis(diphenylphosphine): (-)-SEGPHOS

[0051] Trichlorosilane (3.22 g, 23.3 mmol) was added dropwise to 1.50 g (2.34 mmol) of (-)-SEGPHOSO$_2$, 3.11 g (25.6 mmol) of dimethylaniline and 25 ml of toluene, followed by stirring at 100 °C for 4 hours. The reaction mixture was ice-cooled and 30 ml of 4N aqueous sodium hydroxide solution was added thereto, followed by stirring at room temperature for 30 minutes. After the aqueous layer was separated, the reaction product in the aqueous layer was extracted twice with 15 ml of toluene. A combined solution of the organic layer and the toluene was washed successively twice with 30 ml of hydrochloric acid and water, and 30 ml of an aqueous sodium chloride solution. After drying over anhydrous magnesium sulfate, the solvent was distilled off under reduced pressure and the residue was purified by silica gel column chromatography to obtain 1.21 g (yield 85%) of the titled compound as a colorless solid.
mp : 215-217°C
1H-NMR(CDCl3) : d5.03(2H,d,J=1.6Hz), 5.66(2H,d,J=1.6Hz), 6.51(2H,dd,J=7.9,3.1 Hz), 6.66(2H,d,J=8.1 Hz), 7.11-7.21(20H,m)

Example 6

Preparation of [RuCl(benzene)((-)-SEGPHOS]Cl

[0052] A mixture of [Ru(benzene)Cl$_2$]$_2$ (20.5 mg, 0.041 mmol), (S)-(-)-SEGPHOS (50 mg, 0.081 mmol), 3 ml of methylene chloride and 3 ml of ethanol was stirred in 20 ml of a schrenke tube at 50 °C for 3 hours. The solvent was distilled off, followed by vacuum-drying to give 69.3 mg of the titled compound. 31P-NMR(CDCl3) : d27.0(d,J=62.4 Hz), 41.9 (d,J=62.1 Hz)

Example 7

Synthesis of bis((3,5)-dimethylphenyl)((3,4)-methylenedioxyphenyl)phosphine oxide

[0053] A magnesium (4.2 g, 171 mmol) of was charged into a four-neck round-bottomed flask equipped with a thermometer, a condenser and a pressure equalizing dropping funnel, and then which was completely replaced with nitrogen, and 10 ml of anhydrous tetrahydrofuran was added thereto. To this solution was added a solution of 4-bromo-1,2-methylenedioxybenzene (34.4 g, 171 mmol) in 70ml of THF dropwise over 2.5 hours with water-cooling stirring and successively stirring was further continued at room temperature for 3 hours. To the resulting mixture was added 50 g (171 mmol) of bis((3,5)-dimethylphenyl) phosphinyl chloride in 100 ml of THF dropwise over 1 hours with water-cooling stirring and stirring was continued at room temperature for 15 hours. Thereafter, 10 ml of water was added thereto with ice-cooling to stir for 30 minutes, then 100 ml of 1N hydrochloric acid was added thereto, followed by stirring for 1.5 hours. The product was extracted with 150 ml of ethyl acetate, washed successively with 100 ml of 1N hydrochloric acid, 100 ml of an aqueous saturated sodium bicarbonate solution and 100 ml of water, and the solvent was distilled off under reduced pressure. The residue was purified by silica gel column chromatography (eluent; hexane: ethyl acetate = 1:1) to give 60.0 g of the titled compound.
mp : 154-155°C
1H-NMR(CDCl3) : d2.32(12H,s), 6.02(2H,s), 6.88(1H,dd,J=7.9, 2.3 Hz), 7.07(1H,dd,J-11.3, 1.4 Hz), 7.19(2H,bs), 7.20-7.21(1H,m), 7.25-7.28(4H,m)
31P-NMR(CDCl3) : d30.3

Example 8

Synthesis of bis((3,5)-dimethylphenyl)(2-iodo-(3,4)-methylenedioxyphenyl)phosphine oxide

[0054] Bis((3,5)-dimethylphenyl)((3,4)-methylenedioxyphenyl)phosphine oxide (60.0 g, 158.7 mmol) was dissolved in 330 ml of THF under a nitrogen stream. To this solution was added 250 ml of a solution of lithiumdiisopropylamide in THF (0.7 M) dropwise at - 78 °C over 20 minutes and a temperature was raised to -40 °C. The resulting mixture was cooled to - 78 °C, a solution of 44.6 g (175.7 mmol) of iodine in 160 ml of THF was added dropwise over 20 minutes and, thereafter, a reaction temperature was raised to 0 °C, followed by further stirring for 1 hours. After THF was distilled off, the residue was dissolved with 500 ml of ethyl acetate, washed with 500 ml of an aqueous ammonium chloride solution and 300 ml of a saturated sodium chloride solution and dried over anhydrous magnesium sulfate. The solvent was distilled off under reduced pressure, and the residue was purified by silica gel column chromatography (eluents; hexane:ethyl acetate = 2:5) to obtain 58.9 g of the titled compound.
mp : 229-236°C
1H NMR(CDCl3) : d2.34(12H,bs), 6.10(2H,s), 6.68(1H,dd,J=7.9,2.5 Hz), 6.71(1H,dd,J=20.8,8.0 Hz) 7.17(2H,m), 7.27-7.31(4H,m)
31P-NMR(CDCl3) : d33.9

Example 9

Synthesis of (±)-((5,6),(5',6')-bis(methylenedioxy)biphenyl-2,2"-diyl)bis(bis(3,5-dimethylphenyl)phosphine oxide): (±)-DM-SEGPHOSO$_2$

[0055] A mixture of the iodide (54.0g, 107.2 mol) obtained in Example 8, 20.4 g (321.5 mmol) of copper powders and 210 ml of DMF was heated with stirring at 140 °C for 3 hours under a nitrogen stream. The reaction mixture was filtered with a pad of celite and the solvent was distilled off under reduced pressure. The residue was dissolved in 500 ml of methylene chloride, washed successively with 500 ml of an aqueous ammonium chloride solution and 300 ml of a saturated sodium chloride solution and dried over anhydrous magnesium sulfate. After the solvent was distilled off under reduced pressure, 500 ml of hexane was added to precipitate the crystals. The crystals were collected-filtration, and which was washed with 300 ml of 99.5% ethanol to give 32.0 g of the titled compound.
mp : 256-258°C
1H-NMR(CDCl3) : d2.11(12H,s),2.30(12H,s), 5.43(2H,d,J=1.6Hz), 5.77(2H,d,J=1.6Hz), 6.65(2H,dd,J=8.1,2.0 Hz) 6.92 (2H,dd,J=14.0,8.1 Hz), 6.95(2H,s), 7.09(2H,s), 7.14(4H,d,J=12.2 Hz), 7.37(4H,d,J=12.1 Hz)
31P-NMR(CDCl3) : d30.5
EI-MS m/z 754(M+)

Example 10

Optical resolution of (±)-((5,6),(5',6')-bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(3,5-dimethylphenyl)phosphine oxide): DM-SEGPHOSO$_2$

[0056] (±)-DM-SEGPHOSO$_2$ was separated by resolved using CHIRALCEL OD (20 mm x 250 mm, Eluents: Hexane/2-Propanol = 95/5, Flow: 4.0 ml/min.) to obtain (-)-DM SEGPHOSO$_2$.
mp : 256-258°C
[a]D24-199.7°(c 0.194,CHCl3)

Example 11

Synthesis of (-)-((5,6),(5',6')-bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(3,5-dimethylphenyl)phosphine oxide): (-)-DM-SEGPHOS

[0057] Trichlorosilane (187.6 mg, 1.39 mmol) was added dropwise to the mixture of 99.1 mg (0.131 mmol) of (-)-DM-SEGPHOS02, 191.2 mg (1.58 mmol) of dimethylaniline and 5 ml of toluene, followed by stirring 100 °C for 15 hours. The reaction mixture was ice-cooled, 10 ml of an 1N aqueous sodium hydroxide solution was added thereto, followed by stirring at room temperature for 30 minutes. After the aqueous layer was separated, the aqueous layer was extracted with ethyl acetate, a combined organic layer was washed with 1N hydrochloric acid, water and an aqueous saturated sodium chloride solution. After drying over anhydrous magnesium sulfate, the solvent was distilled off, and the residue was purified by silica gel column chromatography to obtain 49.1 mg (yield 52%) of the titled compound.

Example 12 - 35

[0058] The compounds in the accompanying TABLE were synthesized in analogous manner to Example 1 to 5.

[0059] One enantiomer of the compound specified with the words of HPLC separation' in the sixth column was prepared by HPLC with a preparative chiral column, which was SUMICHIRAL OA-3100 (20mm x 250mm, 5m).

[0060] Abbreviations written in the second column represent following compounds.

DMM-SEGPHOSO$_2$: ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(3,5-dimethyl-4-methoxyphenyl) phosphine oxide)
DMM-SEGPHOS : ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(3,5-dimethyl-4-methoxyphenyl) phosphine)
DTBM-SEGPHOSO$_2$: ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis (3,5-di-t-butyl-4-methoxyphenyl)phosphine oxide)
DTBM-SEGPHOS : ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(3,5-di-*t*-butyl-4-methoxyphenyl) phosphine)
DTB-SEGPHOSO$_2$: ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(3,5-di-t-butylphenyl)phosphine oxide)
DTB-SEGPHOSO$_2$: ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(3,5-di-t-butyl-phenyl)phosphine)
T-SEGPHOSO$_2$: ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(4-methylphenyl)phosphine oxide)
T-SEGPHOS : ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(4-methylphenyl)phosphine)
TB-SEGPHOSO$_2$: ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(4-t-butylphenyl)phosphine oxide)
TB-SEGPHOS : ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(4-t-butylphenyl)phosphine)
p-MeO-SEGPHOSO$_2$: ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(4-methoxyphenyl)phosphine oxide)
p-MeO-SEGPHOS : ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(4-methoxyphenyl)phosphine)
p-Cl-SEGPHOSO$_2$: ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(4-chlorophenyl)phosphine oxide)
p-Cl-SEGPHOS : ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis(4-chlorophenyl)phosphine)
Cy-SEGPHOSO$_2$: ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis (cyclohexyl)phosphine oxide)
Cy-SEGPHOS : ((5,6),(5',6')-Bis(methylenedioxy)biphenyl-2,2'-diyl)bis(bis (cyclohexyl)phosphine)

mp : 246-248°C
1H-NMR(CDCl3) : d 2.09(12H,d,J=0.5 Hz)

Example 36

Preparation of [RuI(p-cymene)((-)-DM-SEGPHOS]I

[0061] A mixture of [Ru(p-cymene)I2]2 (67.4 mg, 0.069 mmol), (-)-DM-SEGPHOS (100.0 mg, 0.138 mmol), 3 ml of methylene chloride and 3 ml of ethanol was stirred in a 20 ml schlenk tube at 50 °C for 3 hours. The solvent was distilled off, followed by vacuum-drying to obtain 167.4 mg of the titled compound.
mp : 246-248°C
1H-NMR(CDCl3) : d 2.09(12H,d,J=0.5 Hz), 2.16(12H,d,J=0.5 Hz),5.19(2H,d,J=1.6 Hz),5.72(2H,d,J=1.6 Hz), 6.56(2H,dd,J=8.0,3.3Hz), 6.67(6H,m), 6.76(2H,m),6.81-6.83(6H,m) 31P-NMR(CDCl3) : d-12.9
CI-MS m/z 722(M+)
[a]D24-114.7°(c 0.095,CHCl3)

Example 37

Preparation of [Rh(cod)((-)-DM-SEGPHOS)]ClO4

[0062] A mixture of [Rh(cod)2]ClO4 (43.0 mg, 0.10 mmol), (-)-DM-SEGPHOS (73.0 mg, 0.10 mmol), 2 ml of methylene chloride and 2 ml of THF was stirred in a 20 ml schlenk tube at room temperature for 15 hours. The solvent was distilled off under reduced pressure, followed by vacuum-drying to obtain 103.3 mg of the titled compound. 31P-NMR (CDCl3) : d 24.5(s), 25.4(s)

Use Example 1

Asymmetric hydrogenation of 2-oxo-1-propanol

[0063] A mixture of 44.8 mg (0.160 mmol) of $[Ru(COD)Cl_2]_2$, 100 mg (0.164 mmol) of (-)-SEGPHOS, 0.12 ml (0.86 mmol) of triethylamine and 5 ml of toluene was heated at reflux for 15 hours under a nitrogen stream. The solvent was distilled off under reduced pressure, followed by vacuum-drying. The resultant $Ru_2Cl_4[(-)\text{-SEGPHOS}]_2NEt_3$ (11.2 mg, 0.0067 mmol), 2-oxo-1-propanol (3.0 g, 0.041 mol) and 6 ml of methanol were placed into a stainless autoclave, followed by heating with stirring at hydrogen pressure of 10 atm at 65 °C for 16 hours. The reaction mixture was measured by GLC and was found to have conversion rate of 99.8% and 97.4%ee.

[0064] Conversion was determined to be 99.8% by using FFAP (25 m x 0.35 mm, I.D. 2.5 mm) according to a conventional method and optical purity was determined to be 97.4%ee by using α-DEX120™ (30 m x 0.25 mm x 0.25 μm) according to a conventional method.

Use Example 2

The asymmetric hydrogenation of methyl 2-benzamidemethyl-3-oxobutyrate

[0065] Methyl 2-benzamidemethyl-3-oxobutyrate (4.98 g, 20 mmol), [RuI(p-cymene)((+)-DM-SEGPHOS]I (12.1 mg, 0.01 mmol), 17.5 ml of methylene chloride and 2.5 ml of methanol were placed into a stainless autoclave, followed by stirring at hydrogen pressure of 10 atm at 70 °C for 20 hours. Conversion and diastereomeric excess were determined by HPLC analysis to be 98.5% and 93.3%de. Optical purity was determined by HPLC analysis to be 99%ee as mosher's ester derived from an optically active α-methoxy-α-trifluoromethylphenyl acetyl chloride and the alcohol obtained.

TABLE

Example	compounds	m.p.(°C)	$[\alpha]_D^{20}$	^{31}P-NMR(ppm)	optical resolution
12	(±)-DMM-SEGPHOSO$_2$	257-258	-	29.27 (s)	
13	(+)-DMM-SEGPHOSO$_2$	153-156	+206.5 (benzene)	-	(+)-DBT
14	(-)-DMM-SEGPHOS	142-144	8.2(benzene)	-14.26(s)	
15	(±)-DTBM-SEGPHOSO$_2$	154-157	-	30.19(s)	
16	(+)-DTBM-SEGPHOSO$_2$	144-145	+36.8(CH_2Cl_2)	-	(-)-DBT
17	(-)-DTBM-SEGPHOS	126-128	54.1(CH_2Cl_2)	-12.31(s)	
18	(±)-DTB-SEGPHOSO$_2$	248-250	-	31.6(s)	
19	(-)-DTB-SEGPHOSO$_2$	133-134	-66.7(CH_2Cl_2)	-	HPLC separation
20	(+)-DTB-SEGPHOS	112-113	+17.6(CH_2Cl_2)	-10.04(s)	
Example	compounds	m.p.(°C)	$[\alpha]_D^{20}$	^{31}P-NMR(ppm)	optical resolution
21	(±)-T-SEGPHOSO$_2$	156-158	-	-29.6(s)	
22	(-)-T-SEGPHOSO$_2$	168-170	-163.3(CH_2Cl_2)	-	(+)-DBT
23	(-)-T-SEGPHOS	188-189	-8.4(CH_2Cl_2)	-13.84(s)	

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TABLE (continued)

24	(±)-TB-SEGPHOSO$_2$	203-205	-	29.49(s)	
25	(+)-TB-SEGPHOSO$_2$	205-208	+110.2(CH_2Cl_2)	-	(-)-DBT
26	(+)-TB-SEGPHOS	290(dec.)	+0.72(CH_2Cl_2)	-15.06(s)	
27	(±)-p-MeO-SEGPHOSO$_2$	122-124	-	29.46(s)	
28	(+)-p-MeO-SEGPHOSO$_2$	144-146	+116.4(CH_2Cl_2)	-	HPLC separation
29	(-)-p-MeO-SEGPHOS	245-246	-3.0(CH_2Cl_2)	-15.5(s)	
30	(±)-p-Cl-SEGPHOSO$_2$	313(dec.)	-	28.72(s)	
31	(+)-p-Cl-SEGPHOSO$_2$	163-165	+102.8(CH_2Cl_2)	-	HPLC separation
32	(+)-p-Cl-SEGPHOS	123-125	+13.5(CH_2Cl_2)	-14.44(s)	
33	(±)-Cy-SEGPHOSO$_2$	270(dec.)	-	46.32(s)	
34	(-)-Cy-SEGPHOSO$_2$	305(dec.)	-24.0(CH_2Cl_2)	-	(-)-DBT
35	(+)-Cy-SEGPHOS	285(dec.)	+0.8(CH_2Cl_2) (c=1.0)	-11.46(s) ($CDCl_3$)	

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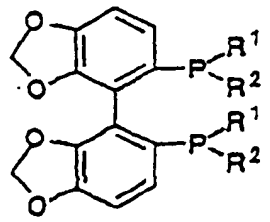
Claims

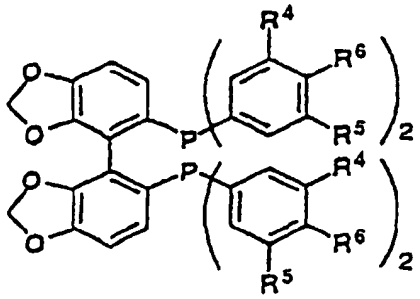
1. A diphosphine compound of the formula (1):



(1)

where R^1 and R^2 represent independently cycloalkyl group, unsubstitued or substituted phenyl group, or five-membered heteroaromatic ring residue.

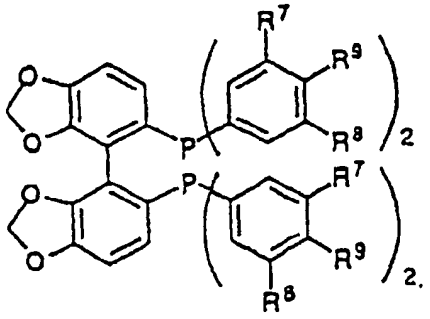
2. A diphosphine compound according to claim 1, in which R^1 and R^2 are identical and represent a phenyl substituted by R^4, R^5 and R^6, said compound having the formula (5) :



(5)

where R^4 and R^5 represent independently hydrogen atom, C_1-C_4 alkyl group or C_1-C_4 alkoxy group; R6 represents hydrogen, C_1-C_4 alkyl group, C_1-C_4 alkoxy group or di(C_1-C_4 alkyl)-amino group.

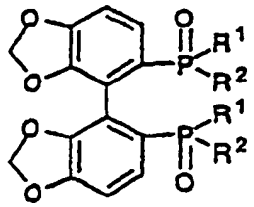
3. A diphosphine compound according to claim 1 or 2, in which R^1 and R^2 are identical and represent a phenyl substituted by R^7, R^8 and R^9, said compound having the formula (6):



(6)

where R7 and R8 are the same or different and represent hydrogen atom, t-butyl group, n-butyl group, n-propyl group, isopropyl group, ethyl group or methyl group; R9 represents hydrogen atom, t-butoxy group, isopropoxy group, ethoxy group or methoxy group.

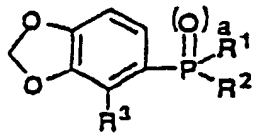
4. A diphosphine compound of the formula (2):



(2)

where R1 and R2 represent independently cycloalkyl group, unsubstituted or substituted phenyl group, or five-membered heteroaromatic ring residue.

5. A phosphine compound of the formula (3):



(3)

where R1 and R2 represent independently cycloalkyl group, unsubstituted or substituted phenyl group, or five-membered heteroaromatic ring residue; R3 represents hydrogen or halogen atom, and letter 'a' represents 0 or 1.

6. A transition metal complex selected from rhodium complex, ruthenium complex, iridium complex, palladium complex and nickel complex, wherein said transition metal complex has as a ligand the compound which is defined in any one of claims 1 to 3 and is optically active.

7. A transition metal complex of the formula (4):

MmLnXpSq (4)

where M represents a transition metal selected from rhodium, ruthenium, iridium, palladium and nickel, L represents the diphosphine compound which is defined in any one of claims 1 to 3 and is optically active, and X and S represent as follows:

when M = Rh, then X = Cl, Br, I, m=n=p=2, q=0
when M = Ru, then m=n=1, X = OAc, p=2, q=0
or X = Cl, S=NEt3, m=n=2, p=4, q=1
or X = methylallyl, m=n=1, p=2, q=0
when M = Ir, then X = Cl, Br, I, m=n=p=2, q=0
when M = Pd, then X = Cl, m=n=1, p= 2, q=0
or X = p-allyl, m=n=p=2, p=0
when M = Ni, then X = Cl, Br, I, m=n=1, p=2, q=0
(Ac represents acetyl group).

8. A catalyst comprising a transition metal complex of the formula (10):

[MmLnXpSq]Yr (10)

where M represents a transition metal selected from rhodium, ruthenium, iridium, palladium and nickel, L represents the diphosphine compound which is defined in any one of claims 1 to 3 and is optically active, and X, S and Y represent as follows:

when M = Rh, then X = cod, nbd, Y=Bf4, ClO4, PF6, BPh4, m=n=p=r=1, q=0

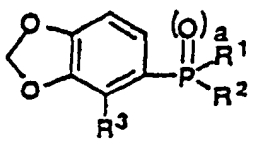
when M = Ru, then X = Cl, Br, I, S=benzene, p-cymene, Y=Cl, Br, I, m=n=p=q=r=1
or Y = BF4, ClO4, PF6, BPh4, m=n=1, p=q=0, r=2
when M = Ir, then X =cod, nbd, Y=BF4, C104, PF6, BPh4, m=n=r=1, p=1, q=0
when M = Pd, then Y= BF4, C104, PF6, BPh4, m=n=r=1, p=q=0

(cod represents 1,5-cyclooctadiene, nbd represents norbornadiene, and Ph represents phenyl group).

9. A catalyst for asymmetric hydrogenation comprising the transition metal complex according to claim 6 or 7.

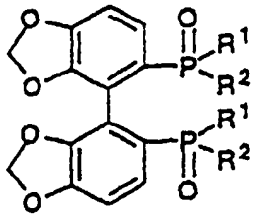
10. Method of preparing a compound having formula (1) according to claim 1, comprising the steps of:

a) reacting a 3,4 - methylenedioxyhalogenobenzene successively with Mg, a corresponding derivative of phosphinyl chloride and optionally a halogen, in an appropriate solvent, thereby obtaining a compound having formula (3) :



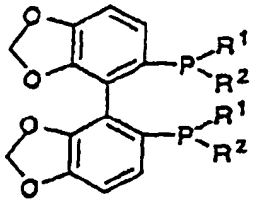
(3)

in which R1 and R2 independently signify cycloalkyl group, unsubstituted or substituted phenyl group, or five-membered heteroaromatic ring residue and R3 signifies hydrogen or a halogen atom ; and where letter a signifies 1 ;
b) condensing said compound having formula (3) into a compound having formula (2):



(2)

in which R1 and R2 have the same meaning as described above ;and
c) reducing said compound having formula (2), thereby obtaining a compound having formula (1) :

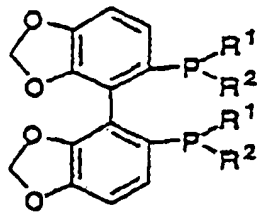


(1)

in which R1 and R2 have the same meaning as described above.

Patentansprüche

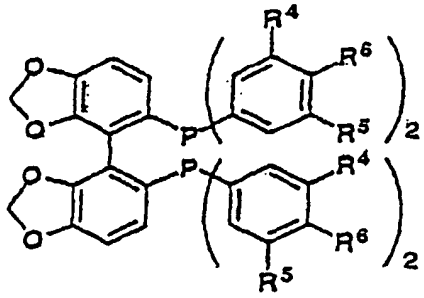
1. Diphosphinverbindung der Formel (1):



(1)

wobei R^1 und R^2 unabhängig voneinander für einen Cycloalkylrest, einen unsubstituierten oder substituierten Phenylrest oder einen Rest eines fünfgliedrigen heteroaromatischen Rings stehen.

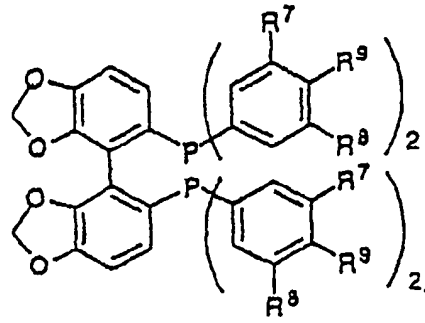
2. Diphosphinverbindung gemäß Anspruch 1, wobei R^1 und R^2 identisch sind und für einen Phenylrest substituiert mit R^4, R^5 und R^6 stehen, wobei die Verbindung die Formel (5) aufweist:



(5)

wobei R^4 und R^5 unabhängig voneinander für ein Wasserstoffatom, einen C_1-C_4-Alkylrest oder einen C_1-C_4-Alkoxyrest stehen; R^6 für ein Wasserstoffatom, einen C_1-C_4-Alkylrest, einen C_1-C_4-Alkoxyrest oder einen Di(C_1-C_4-alkyl)-aminorest steht.

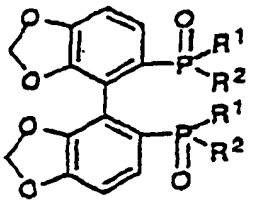
3. Diphosphinverbindung gemäß Anspruch 1 oder 2, wobei R^1 und R^2 identisch sind und für einen Phenylrest substituiert mit R^7, R^8 und R^9 stehen, wobei die Verbindung die Formel (6) aufweist:



(6)

wobei R^7 und R^8 gleich oder verschieden sind und für ein Wasserstoffatom, eine *t*-Butylgruppe, eine *n*-Butylgruppe, eine *n*-Propylgruppe, eine Isopropylgruppe, eine Ethylgruppe oder eine Methylgruppe stehen; und R^9 für ein Wasserstoffatom, eine *t*-Butoxygruppe, eine Isopropoxygruppe, eine Ethoxygruppe oder eine Methoxygruppe steht.

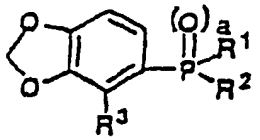
4. Diphosphinverbindung der Formel (2):



(2)

wobei R^1 und R^2 unabhängig voneinander für einen Cycloalkylrest, einen unsubstituierten oder substituierten Phenylrest oder einen Rest eines fünfgliedrigen heteroaromatischen Rings stehen.

5. Phosphinverbindung der Formel (3):



(3)

wobei R^1 und R^2 unabhängig voneinander für einen Cycloalkylrest, einen unsubstituierten oder substituierten Phenylrest oder einen Rest eines fünfgliedrigen heteroaromatischen Rings stehen; R^3 für ein Wasserstoff- oder Halogenatom steht und der Buchstabe "a" für 0 oder 1 steht.

6. Übergangsmetallkomplex, ausgewählt aus einem Rhodiumkomplex, einem Rutheniumkomplex, einem Iridiumkomplex, einem Palladiumkomplex und einem Nickelkomplex, wobei der Übergangsmetallkomplex als Liganden eine Verbindung, welche in-einem der Ansprüche 1 bis 3 definiert ist und optisch aktiv ist, aufweist.

7. Übergangsmetallkomplex der Formel (4):

$$M_mL_nX_pS_q \qquad (4)$$

wobei M für ein Übergangsmetall, ausgewählt aus Rhodium, Ruthenium, Iridium, Palladium und Nickel steht, L für die Diphosphinverbindung, welche in einem der Ansprüche 1 bis 3 definiert ist und optisch aktiv ist, steht und X und S wie folgt definiert sind:

wenn M = Rh, dann ist X = Cl, Br, I, m = n = p = 2, q = 0
wenn M = Ru, dann istm = n = 1, X = OAc, p =2, q =0
oder X = Cl, S = NEt_3, m = n = 2, p = 4, q = 1
oder X = Methylallyl, m = n = 1, p = 2, q = 0
wenn M = Ir, dann ist X = Cl, Br, I, m = n = p = 2, q = 0
wenn M = Pd, dann ist X = Cl, m = n = 1, p = 2, q = 0
oder X = p-Allyl, m = n = p = 2, q = 0
wenn M = Ni, dann ist X = Cl, Br, I, m = n = 1, p = 2, q = 0

(Ac steht für eine Acetylgruppe).

8. Katalysator, umfassend einen Übergangsmetallkomplex der Formel (10):

$$[M_mL_nX_pS_q]Y_r \qquad (10)$$

wobei M für ein Übergangsmetall, ausgewählt aus Rhodium, Ruthenium, Iridium, Palladium und Nickel, steht, L für die Diphosphinverbindung, welche in einem der Ansprüche 1 bis 3 definiert ist und optisch aktiv ist, steht und

X, S und Y wie folgt definiert sind:

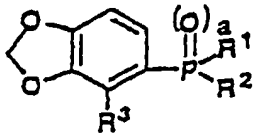
wenn M = Rh, dann ist X = cod, nbd, Y = BF_4, ClO_4, PF_6, BPh_4, m = n = p = r = 1, q = 0
wenn M = Ru, dann ist X = Cl, Br, I, S = Benzol, p-Cymen, Y = Cl, Br, I, m = n = p = q=r=1
oder Y = BF_4, ClO_4, PF_6, BPh_4, m = n = 1, p = q = 0, r = 2
wenn M = Ir, dann ist X = cod, nbd, Y = BF_4, ClO_4, PF_6, BPh_4, m = n = r = 1, p = 1, q = 0
wenn M = Pd, dann ist Y = BF_4, ClO_4, PF_6, BPh_4, m = n = r = 1, p = q = 0

(cod steht für eine 1,5-Cyclooctadiengruppe, nbd steht für eine Norbornadiengruppe und Ph steht für eine Phenylgruppe).

9. Katalysator zur asymmetrischen Hydrierung, umfassend den Übergangsmetallkomplex nach Anspruch 6 oder 7.

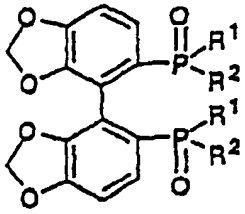
10. Verfahren zur Herstellung einer Verbindung der Formel (1) nach Anspruch 1, umfassend die Schritte:

a) Umsetzen von 3,4-Methylendioxyhalogenbenzol der Reihe nach mit Mg, einem entsprechenden Derivat von Phosphinylchlorid und gegebenenfalls einem Halogen in einem geeigneten Lösungsmittel, um eine Verbindung der Formel (3) zu erhalten:



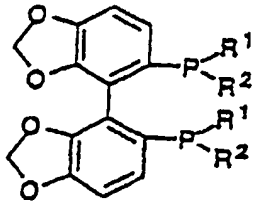
(3)

wobei R^1 und R^2 unabhängig voneinander für einen Cycloalkylrest, einen unsubstituierten oder substituierten Phenylrest oder einen Rest eines fünfgliedrigen heteroaromatischen Rings stehen und R^3 für ein Wasserstoff- oder Halogenatom steht; und wobei der Buchstabe "a" für 1 steht;
b) Kondensation der Verbindung der Formel (3) zu einer Verbindung der Formel (2):



(2)

wobei R^1 und R^2 die vorstehend angegebene Bedeutung haben; und
c) Reduktion der Verbindung der Formel (2), um eine Verbindung der Formel (1) zu erhalten:

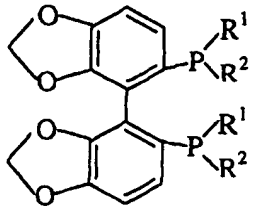


(1)

wobei R^1 und R^2 die vorstehend angegebene Bedeutung haben.

Revendications

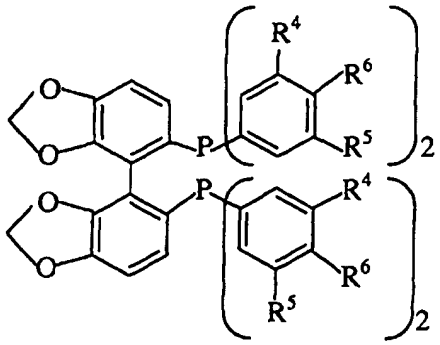
1. Composé de diphosphine de formule (1) :



(1)

où R^1 et R^2 représentent de façon indépendante un groupe cycloalkyle, un groupe phényle substitué ou non substitué ou un résidu de cycle hétéroaromatique à cinq membres.

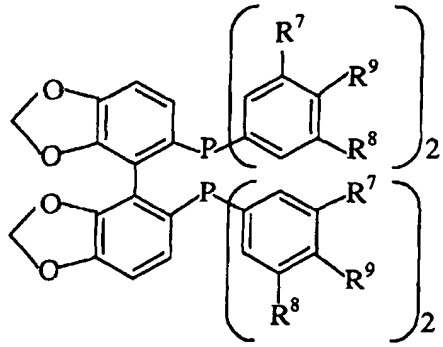
2. Composé de diphosphine selon la revendication 1, dans lequel R^1 et R^2 sont identiques et représentent un phényle substitué par R^4, R^5 et R^6, ledit composé ayant la formule (5) :



(5)

où R^4 et R^5 représentent de façon indépendante un atome d'hydrogène, un groupe alkyle en C_1-C_4 ou un groupe alcoxy en C_1-G_4 ; R^6 représente un hydrogène, un groupe alkyle en C_1-C_4, un groupe alcoxy en C_1-C_4 ou un groupe di-(alkyle en C_1-C_4)-amino.

3. Composé de diphosphine selon la revendication 1 ou 2, dans lequel R^1 et R^2 sont identiques et représentent un phényle substitué par R^7, R^8 et R^9, ledit composé ayant la formule (6) :

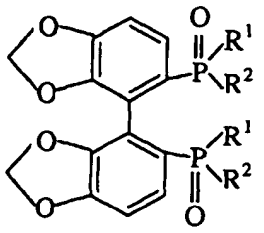


(6)

où R^7 et R^8 sont identiques ou différents et représentent un atome d'hydrogène, un groupe *t*-butyle, un groupe n-butyle, un groupe n-propyle, un groupe isopropyle, un groupe éthyle ou un groupe méthyle ; R^9 représente un

atome d'hydrogène, un groupe *t*-butoxy, un groupe isopropoxy, un groupe éthoxy ou un groupe méthoxy.

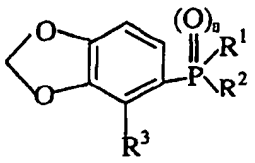
4. Composé de diphosphine de formule (2) :



(2)

où R^1 et R^2 représentent de façon indépendante un groupe cycloalkyle, un groupe phényle substitué ou non substitué ou un résidu de cycle hétéroaromatique à cinq membres.

5. Composé de phosphine de formule (3) :



(3)

où R^1 et R^2 représentent de façon indépendante un groupe cycloalkyle, un groupe phényle substitué ou non substitué ou un résidu de cycle hétéroaromatique à cinq membres ; R^3 représente un hydrogène ou un atome d'halogène ; et la lettre "a" représente 0 ou 1.

6. Complexe d'un métal de transition choisi parmi un complexe du rhodium, un complexe du ruthénium, un complexe de l'iridium, un complexe du palladium et un complexe du nickel, dans lequel ledit complexe de métal de transition a pour ligand le composé qui est défini dans l'une quelconque des revendications 1 à 3 et qui est optiquement actif.

7. Complexe d'un métal de transition de formule (4) :

$$M_mL_nX_pS_q \qquad (4)$$

où M représente un métal de transition choisi entre le rhodium, le ruthénium, l'iridium, le palladium et le nickel, L représente le composé de diphosphine qui est défini dans l'une quelconque des revendications 1 à 3 et qui est optiquement actif et X et S représentent les composés suivants :

lorsque M = Rh, alors X = Cl, Br, I, m=n=p=2, q=0
lorsque M = Ru, alors m=n=1, X = OAc, p=2, q=0
ou X = Cl, S = NEt_3, m=n=2, p=4, q=1
ou X = méthylallyle, m=n=1, p=2, q=0
lorsque M = Ir, alors X = Cl, Br, I, m=n=p=2, q=0
lorsque M = Pd, alors X = Cl, m=n=1, p=2, q=0
ou X = *p*-allyle, m=n=p=2, p=0
lorsque M = Ni, alors X = Cl, Br, I, m=n=1, p=2, q=0

(Ac représente le groupe acétyle).

8. Catalyseur comprenant un complexe de métal de transition de formule (10) :

$$[M_mL_nX_pS_q]Y_r \quad (10)$$

où M représente un métal de transition choisi entre le rhodium, le ruthénium, l'iridium, le palladium et le nickel, L représente le composé de diphosphine qui est défini dans l'une quelconque des revendications 1 à 3 et qui est optiquement actif et X, S et Y représentent les composés suivants :

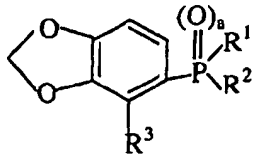
lorsque M = Rh, alors X = cod, nbd, Y = BF_4, ClO_4, PF_6, BPh_4, m=n=p=r=1, q=0
lorsque M = Ru, alors X = Cl, Br, I, S = benzène, *p*-cymène, Y = Cl, Br, I, m=n=p=q=r=1
ou Y = BF_4, ClO_4, PF_6, BPh_4, m=n=1, p=q=0, r=2
lorsque M = Ir, alors X = cod, nbd, Y = BF_4, ClO_4, PF_6, BPh_4, m=n=r=1, p=1, q=0
lorsque M = Pd, alors Y = BF_4, ClO_4, PF_6, BPh_4, m=n=r=1, p=q=0

(cod représente le 1,5-cyclooctadiène, nbd représente le norbornadiène et Ph représente le groupe phényle).

9. Catalyseur d'hydrogénation asymétrique comprenant le complexe de métal de transition selon la revendication 6 ou 7.

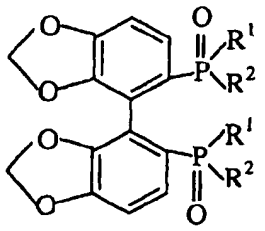
10. Procédé pour préparer un composé ayant la formule (1) selon la revendication 1, comprenant les étapes consistant à :

a) faire réagir un 3,4-méthylènedioxyhalogénobenzène successivement avec Mg, avec un dérivé correspondant de chlorure de phosphinyle et de façon facultative avec un halogène, dans un solvant approprié, pour obtenir un composé ayant la formule (3) :



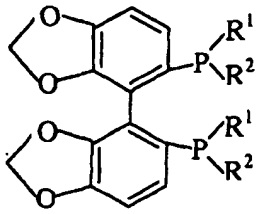
(3)

dans laquelle R^1 et R^2 représentent de façon indépendante un groupe cycloalkyle, un groupe phényle substitué ou non substitué ou un résidu de cycle hétéroaromatique à cinq membres et R^3 représente un hydrogène ou un atome d'halogène ; et où la lettre a représente 1 ;
b) condenser ledit composé ayant la formule (3) en un composé ayant la formule (2) :



(2)

dans laquelle R^1 et R^2 ont la même signification que celle décrite ci-dessus ; et
c) réduire ledit composé ayant la formule (2), pour obtenir un composé ayant la formule (1):



(1)

dans laquelle R^1 et R^2 ont la même signification que celle décrite ci-dessus.